

**JOHN FLUKE MFG. CO., INC.**

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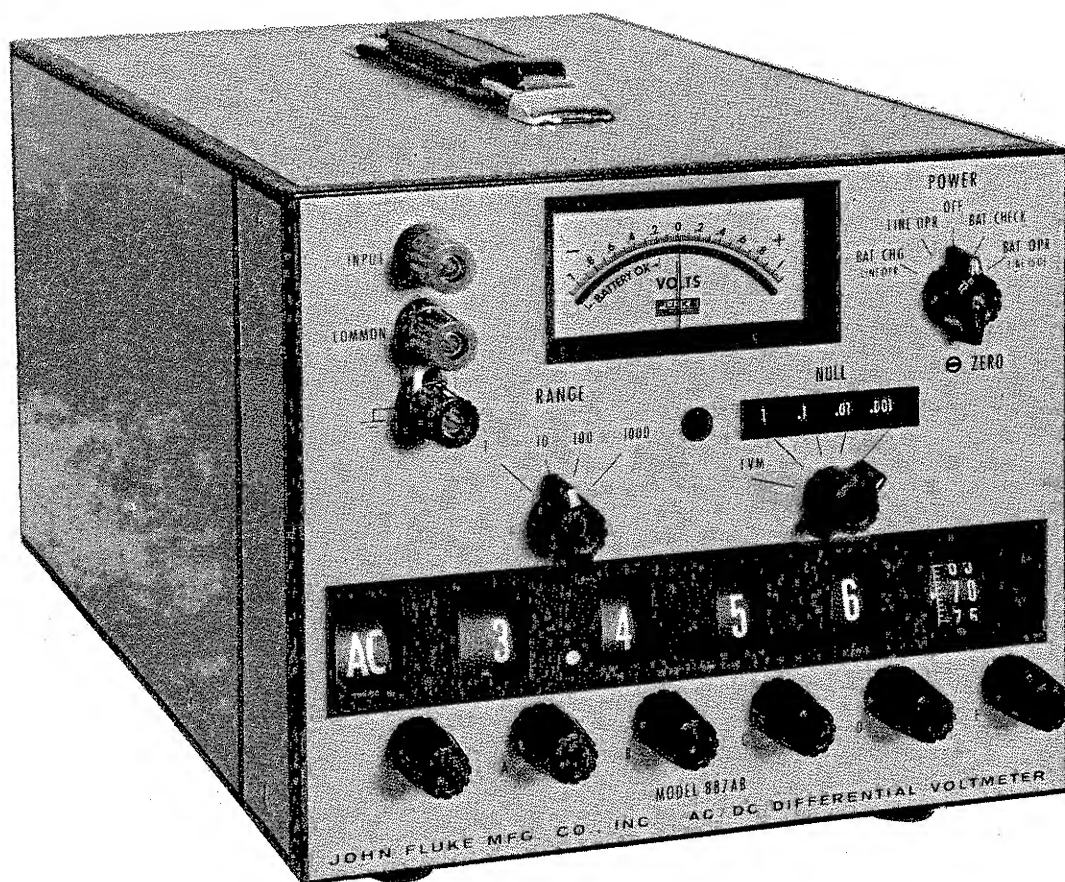
**MODEL 887A & 887AB**

**AC/DC DIFFERENTIAL  
VOLTMETERS**

**Rev. 1, May, 1973**

**Rev. 2 Aug., 1973**





MODEL 887AB AC/DC DIFFERENTIAL VOLTMETER



## SECTION I

# INTRODUCTION AND SPECIFICATIONS

### I-1. INTRODUCTION

1-2. This instruction manual is for use with the 887A series Differential AC/DC voltmeters. These are available as either a line-powered instrument (Model 887A) or as a combination line-powered or battery-powered instrument (Model 887AB). Both instruments are half rack size and are equipped with resilient feet and tilt-up bail for field or bench use. A single instrument may be mounted in a standard 19 inch rack by means of metal handle rack adapter kit 881A-102. Two instruments may be mounted side-by-side by means of metal handle rack adapter kit 881A-103.

1-3. The 887A/AB series instruments are capable of being used as conventional voltmeters for rapid determination of voltages from 0 to 1100 volts dc and from 0.001 to 1100 volts ac to within  $\pm 3\%$  of range setting; as differential voltmeters for precise measurement of dc voltages from 0 to  $\pm 1100$  volts to within  $\pm (0.0025\%$  of input  $+ 0.0001\%$  of range  $+ 5\mu\text{v}$ ); as accurate ac voltmeters for measurement of ac voltages from 0.001 to 500 volts to within  $\pm (0.05\%$  of input  $+ 0.0025\%$  of range) from 30 Hz to 5 kHz, with reduced accuracy to 5 Hz and 100 kHz; and as megohmmeters for measurement of resistance from 10 megohms to 11,000 megohms with a typical accuracy of 5%. They can also be used to measure the excursions of a voltage about some nominal value. One feature that should be emphasized is that no current is drawn from the unknown source at null up to 11 volts dc. Thus the determination of the unknown potential is independent of its source resistance. Above 11 volts dc, the input resistance is an excellent 10 megohms. To minimize errors due to common mode voltages, the 887A series is provided with extremely high leakage resistance to ground - typically several hundred thousand megohms. Also, where ground loops errors are a problem, the battery operated mode of the 887AB eliminates these errors due to complete isolation from the power line. As additional features, the 887A series contains a polarity switch for equal convenience in measuring positive or negative dc voltages and an adjustable recorder output which makes the instrument particularly useful for monitoring the stability of almost any ac or dc voltage. Furthermore, thorough shock, vibration, humidity, and temperature testing assure years of hard use under severe environmental conditions.

1-4. When used as a dc differential voltmeter, the 887A operates on the potentiometric principal. An unknown voltage is measured by comparing it to a known adjustable voltage with the aid of a null detector. An accurate standard for measurement is obtained from 11 volt dc reference supply derived from a pair of temperature-compensated zener diodes. The known adjustable reference voltage is provided by a Kelvin-Varley voltage divider with four decades of FLUKE precision wirewound resistors and a high-resolution interpolating vernier that are set accurately by five voltage readout dials to give a six digit readout. In this way, the 11 volts can be precisely divided into increments smaller than 10 microvolts. The unknown voltage is then simply read from the voltage dials. For voltages between 11 and 1100 volts dc, an input attenuator divides the unknown voltage by 100 before it is measured potentiometrically. When used as an accurate ac voltmeter, the 887A operates essentially the same as for dc differential measurements. The ac input voltage is converted to a dc voltage and this dc voltage is measured by comparing it to a known adjustable reference voltage.

### I-5. INPUT POWER

1-6. Like most FLUKE instruments, the 887A is normally supplied with dual primary windings connected in parallel for 115 volt line operation. Upon request, the instrument is supplied for 230 volt line operation with the primary windings connected in series. If it becomes desirable to convert from one mode of operation to the other, refer to the instruction decal on the power transformer.

### I-7. DAMAGE IN SHIPMENT

1-8. Immediately upon receipt, thoroughly inspect the instrument for any damage that may have occurred in transit. If any damage is noted, follow the instructions outlined on the warranty page at the back of this manual.

## 1-7. SPECIFICATIONS

**AS A DIFFERENTIAL VOLTMETER**

**DC ACCURACY.**  $\pm(0.0025\%$  of input +  $0.0001\%$  of range + 5 uv) from 0 to  $\pm 1100$  vdc at  $23^{\circ}\text{C}$ . (nominal calibration temperature), less than 70% relative humidity.  $\pm(0.005\%$  of input + 5 uv) from 0 to  $\pm 1100$  vdc within  $16^{\circ}\text{C}$  to  $32^{\circ}\text{C}$  ( $60^{\circ}\text{F}$  to  $90^{\circ}\text{F}$ ) temperature range, less than 70% relative humidity. Derate accuracy outside this temperature range at  $0.00035\%/^{\circ}\text{C}$  to extremes of  $0^{\circ}\text{C}$  and  $50^{\circ}\text{C}$  ( $32^{\circ}\text{F}$  and  $122^{\circ}\text{F}$ ).

**NOTE.** Thorough error analysis studies were made into total instrument stability taking into account the documented stabilities of individual components and utilizing probability and statistical methods. These studies indicate that typical instrument stability defined as a specification met by 80% to 90% of all instruments is 20 ppm ( $0.002\%$ ) peak-to-peak per year.

**AC ACCURACY.** At  $23^{\circ}\text{C} \pm 1^{\circ}\text{C}$  (nominal calibration temperature) relative humidity less than 70%

INPUT VOLTAGE	FREQUENCY		
	30Hz to 5KHz	5KHz to 10KHz	10KHz to 20KHz
.001 to 500V	$\pm(0.05\%$ of input + $0.0025\%$ range)	$\pm(0.07\%$ of input + $0.005\%$ range)	$\pm(0.15\%$ of input + $0.01\%$ range)
500V to 1100V	$\pm 0.1\%$ of input	$\pm 0.1\%$ of input	$\pm(0.15\%$ of input + $0.01\%$ range)

Temperature range  $13^{\circ}\text{C}$  to  $35^{\circ}\text{C}$  ( $55^{\circ}\text{F}$  to  $95^{\circ}\text{F}$ ) relative humidity less than 70%

INPUT VOLTAGE	LOW FREQUENCY		BASIC FREQUENCY		HIGH FREQUENCY		
	5Hz - 10Hz	10Hz - 20Hz	20Hz - 5KHz	5KHz - 10KHz	10KHz - 20KHz	20KHz - 50KHz	50KHz - 100KHz
.001 - 1100V	$\pm(1\%$ of input + 25 uv)	$\pm(0.3\%$ of input + 100uv)	$\pm(0.1\%$ of input + 25 uv)	$\pm(0.15\%$ of input + 25 uv)			
0.1 - 1100V					$\pm 0.3\%$ of input		
0.1 - 110V						$\pm 0.5\%$ of input	$\pm 1\%$ of input

Outside the  $13^{\circ}\text{C}$  to  $35^{\circ}\text{C}$  temperature range the above specifications may be derated at  $0.003\%/^{\circ}\text{C}$  (below 5 KHz) or  $0.005\%/^{\circ}\text{C}$  (above 5 KHz) to the extremes of  $0^{\circ}\text{C}$  to  $50^{\circ}\text{C}$  ( $32^{\circ}\text{F}$  to  $122^{\circ}\text{F}$ )

**AS A CONVENTIONAL VOLTMETER**

**AC ACCURACY.**  $\pm 3\%$  of range within frequency and voltage ranges listed under "ac accuracy as a differential voltmeter."

**DC ACCURACY.**  $\pm 3\%$  of range.

**RANGE**

VOLTAGE RANGE	DC INPUT RESISTANCE	AC INPUT IMPEDANCE
1000-0-1000	10 MEG	1 MEG 40 Pf
100-0-100	10 MEG	1 MEG 40 Pf
10-0-10	10 MEG	1 MEG 40 Pf
1-0-1	10 MEG	1 MEG 40 Pf
*.1-0-.1	10 MEG	1 MEG 40 Pf
*.01-0-.01	10 MEG	1 MEG 40 Pf
*.001-0-.001	1 MEG	1 MEG 40 Pf
*.0001-0-.0001	1 MEG	1 MEG 40 Pf

**NOTE.** 10% overvoltage capability on each range.

\* These ranges obtained by using null ranges with all voltage readout dials set to zero.

An instrument so categorized need be calibrated only once per year to meet all specifications. Additional stability data upon request.

**VOLTAGE RANGES.** 1, 10, 100, 1000 vac and dc, with 10% overranging capability on each range.

**NULL RANGES.** 100 uv through 100 v end scale ac and dc, in seven ranges.

**DC INPUT RESISTANCE.** Infinite at null from 0 to  $\pm 11$  vdc. 10 megohms above  $\pm 11$  vdc.

**METER RESOLUTION.** 1 ppm of range (1 uv maximum).

**VOLTAGE DIAL RESOLUTION.** 1 pom of range (1 uv maximum).

GENERAL

**ELECTRICAL DESIGN.** Completely solid-state.

**INPUT RESISTANCE OF NULL DETECTOR.** 10 meg-ohms for two least sensitive null ranges, all input ranges; 1 megohm for two most sensitive null ranges, all input ranges.

**REFERENCE ELEMENT.** Temperature-compensated zener diode, temperature coefficient less than 1 ppm/°C over operating temperature range.

**REGULATION OF REFERENCE SUPPLY.** 0.0002% for 10% line voltage change.

**STABILITY OF REFERENCE SUPPLY.** 0.0005% peak-to-peak per hour. 0.0007% peak-to-peak per day. 0.0013% peak-to-peak per sixty days.

**STABILITY OF INSTRUMENT.** 0.0025% peak-to-peak per sixty days.

**ACCURACY OF OFF-NUL DEFLECTION.**  $\pm 5\%$  of null range ( $\pm 3\%$  with voltage dials at zero).

**KELVIN VARLEY DIVIDER ACCURACY.**  $\pm 0.0012\%$  of setting from 1/10 of full scale to full scale.  $\pm 0.00012\%$  terminal linearity below 1/10 full scale.

**RECORDER OUTPUT.** Adjustable from 0 to  $\pm 20$  mv minimum for full scale right and left deflection.

**POLARITY.** Front panel switch selects +DC, -DC and AC.

**WARMUP TIME.** Three minutes.

**COMMON MODE REJECTION.** 130 db DC; 85 db at 60 Hz; 70 db-at 400 Hz. Note: Battery operation of Model 887AB provides complete isolation from power system ground, for elimination of error due to ground loops.

**OPERATING TEMPERATURE RANGE.** 0°C to 50°C (see accuracy).

**STORAGE TEMPERATURE RANGE.**

Model 887A, -40°C to +70°C (-40°F to +158°F)

Model 887AB, -40°C to -60°C (-40°F to +140°F)

**SHOCK.** Meets requirements of MIL-T-945A and MIL-S-901B.

**VIBRATION.** Meets requirements of MIL-T-945A.

**INPUT POWER.** Model 887A 115/230 vac  $\pm 10\%$ , 50 to 440 Hz; Model 887AB 115/230 vac  $\pm 10\%$ , 50 to 440 Hz and rechargeable battery operation (minimum 30 hours operation on full charge).

**WEIGHT.**

Model 887A approximately 13 lbs.

Model 887AB approximately 14 lbs.

**SIZE.** 7" high, 8 1/2" wide, 14 3/4" deep.





## SECTION II

# OPERATING INSTRUCTIONS

### 2-1. FUNCTION OF EXTERNAL CONTROLS, TERMINALS AND INDICATORS

2-2. The location, circuit symbol, and a functional description of the external controls, terminals, and indicators on the 887A and 887AB Precision Differential DC Voltmeter may be found in figure 2-1 and 2-2.

### 2-3. PRELIMINARY OPERATION FOR 887A

2-4. The following procedure prepares the Model 887A for operation.

- a. Connect power plug to a 115 volt ac power outlet. If instrument has been wired for 230 volt operation, connect to 230 volts ac.

#### WARNING!

The round pin on polarized three-prong plug connects instrument case to power system ground. Use a three-to-two pin adapter when connecting to a two-contact receptacle. For personnel safety, connect short green lead to a good earth ground.

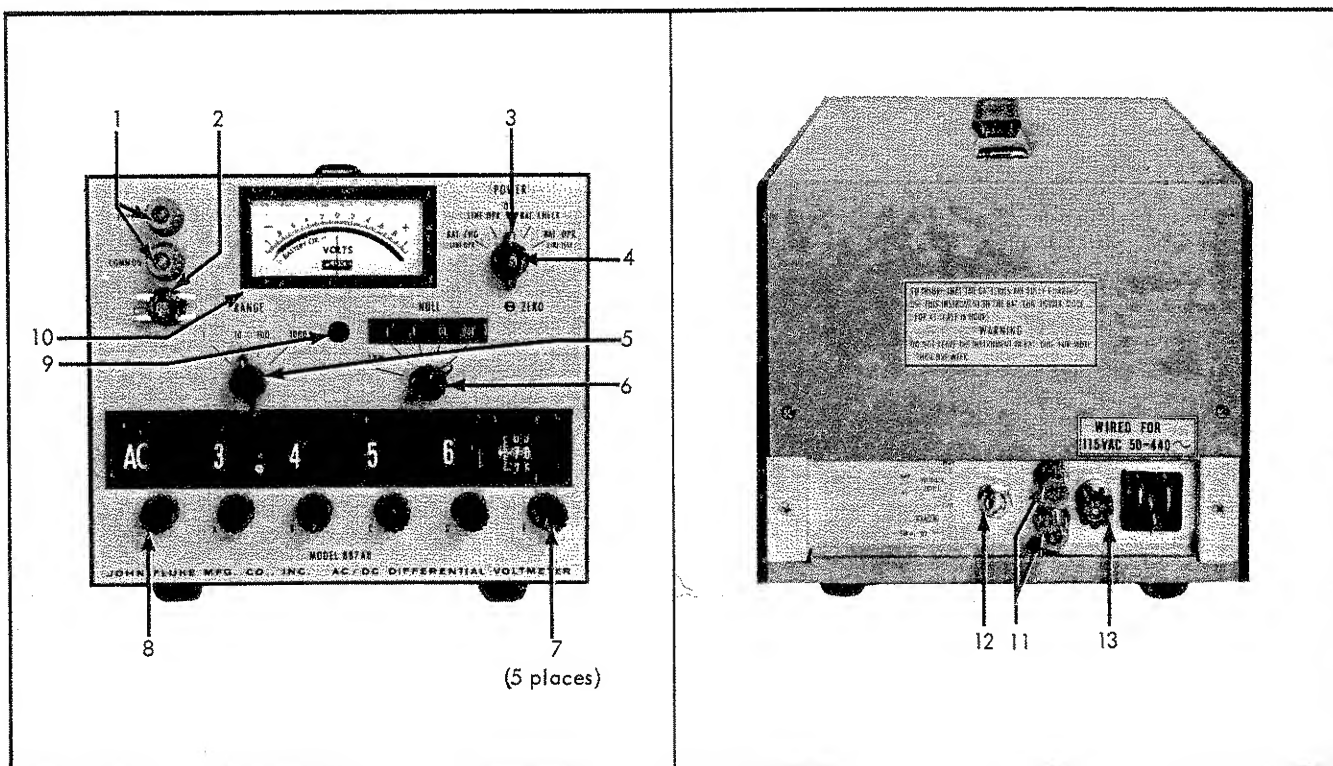


Figure 2-1. LOCATION OF CONTROLS, TERMINALS, AND INDICATORS

INDEX NO.	CONTROLS TERMINALS AND INDICATORS	CIRCUIT SYMBOL	FUNCTIONAL DESCRIPTION
1	INPUT and COMMON terminals	J1, J2	Provided for connecting ac or dc voltage to be measured.
2	Chassis ground terminal	J3	Provided for grounding purposes. A 0.01 uf capacitor is connected from the COMMON binding post to the chassis ground post. The INPUT post should never be connected to the chassis ground post. Since the instrument is equipped with a three-wire line cord with the third wire fastened to the chassis, the circuit should be checked for conflicts in grounding before connecting COMMON binding post to the chassis post.
3	POWER switch	S1	In the Model 887A, the POWER switch applies ac line voltage to primary circuit of transformer when turned from OFF to ON. In the Model 887AB, positions for OFF, BAT CHECK, and three modes of operation (LINE OPR, BAT CHG - LINE OPR, and BAT OPR - LINE ISOL) are available. When set to LINE OPR, ac line voltage is applied to primary circuit of transformer. When set to BAT CHG - LINE OPR, ac line voltage is applied to primary of transformer and batteries are charged at the same time. When set to BAT OPR - LINE ISOL, battery power is applied to the instrument and both sides of primary circuit are open. When set to BAT CHECK, battery power is applied to the instrument, both sides of primary circuit are open, and meter is connected in series with a resistor to measure voltage between reference supply batteries and reference supply output which indicates the condition of the batteries.
4	Electronic ZERO control	R239	A screwdriver adjustment used to zero null detector in the .0001 volt null mode on the 1 volt range and in the .01 volt null mode on the 100 volt range. For best results, input should be shorted prior to zeroing.
5	RANGE switch	S2	Selects desired voltage range, changes null ranges appearing in NULL window, and positions decimal point for voltage readout dials. Voltage ranges of 1, 10, 100, and 1000 volts are available. A voltage 10% higher than range setting may be measured in each range.
6	NULL switch	S3	Set to TVM for determining the approximate value of unknown voltage prior to differential measurements. Seven null voltage ranges (four of which are used for each setting of the RANGE switch) of 100, 10, 1, 0.1, 0.01, 0.001, and 0.0001 volts are used for differential measurements. These ranges represent full scale differences between the unknown voltage and the amount of precision internal reference voltage that is set on the voltage readout dials.
7	A, B, C, D, and E voltage readout dials	S5, S6, S7, S8, R13	Provide an in-line readout of the amount of internal reference voltage necessary to null the unknown voltage.
8	AC-DC polarity switch	S4	Selects the AC, + (dc), or - (dc) mode of operation. With this switch in the positive position, the polarity of INPUT binding post is positive with respect to COMMON binding post.

Figure 2-2. DESCRIPTION OF CONTROLS, TERMINALS, AND INDICATORS (Sheet 1 of 2)

INDEX NO.	CONTROLS TERMINALS AND INDICATORS	CIRCUIT SYMBOL	FUNCTIONAL DESCRIPTION
9	Mechanical zero control	None	Sets meter to zero mechanically. This adjustment should be used only after instrument has been turned off for at least three minutes or when the internal meter terminals have been shorted.
10	Meter	M1	Indicates approximate voltage when 887A is in TVM mode and difference between unknown and internal reference voltage when 887A is in differential mode.
11	RECORDER OUTPUT terminals	J4, J5	Provided for attaching a recorder to monitor voltage excursions.
12	AMP ADJ control	R8	Varies the output level of the output binding post from 0 to at least 20 millivolts at full scale deflection.
13	Fuse	F1	Fuse holder protrudes from instrument to provide easy access to the fuse. The fuse is a 1/16 ampere slow blowing type for 115 volt operation and a 1/32 ampere slow blowing type for 230 volt operation.

Figure 2-2. DESCRIPTION OF CONTROLS, TERMINALS, AND INDICATORS (Sheet 2 of 2)

- b. Set switches on 887A voltmeter as follows:

RANGE	1000
NULL	TVM
ac-dc polarity	+ (positive)
all voltage readout dials	0 (zero)
POWER	ON

ac-dc polarity	+ (positive)
all voltage readout dials	0 (zero)

## 2-5. PRELIMINARY OPERATION FOR 887AB

2-6. The following procedure prepares the Model 887AB for operation.

- a. For line operation, connect power plug to a 115 volt ac power outlet. If instrument has been wired for 230 volt operation, connect to 230 volts ac.

### WARNING

The round pin on polarized three-prong plug connects instrument case to power system ground. Use a three-to-two pin adapter when connecting to a two-contact receptacle. For personnel safety, connect short green lead to a good earth ground.

- b. For line operation, set POWER switch to LINE OPR.

c. For battery operation, set POWER switch to BAT CHECK. Meter needle should deflect to BATTERY OK region. If meter needle does not stay within BATTERY OK region for 10 seconds, charge batteries as outlined in paragraph 2-9. If batteries are charged, set POWER switch to BAT OPR-LINE ISOL.

- d. Set switches on 887AB voltmeter as follows:

RANGE	1000
NULL	TVM

## 2-7. ZEROING INSTRUCTIONS

2-8. From time to time, it may be necessary to adjust the electronic meter zero control. This will normally be done at somewhat more frequent intervals than complete instrument calibration. Proceed as follows:

- a. Perform preliminary operation as stated in paragraph 2-3 or 2-5.

b. Mechanically zero the meter with the adjustment screw on the front of the meter case. If the instrument is in the case, it must be shut off for at least three minutes prior to this adjustment. If out of case, another method would be to short out the internal panel meter terminals prior to zeroing.

- c. Turn instrument on and allow a 5 minute warmup period.

d. Set RANGE switch to 1, voltage readout dials to zero, and NULL switch to 0.0001.

e. Short INPUT post to COMMON post and adjust electronic ZERO control with a screwdriver for zero meter deflection.

- f. Remove short from between INPUT and COMMON post.

## 2-9. BATTERY CHARGING

a. Connect power plug to a 115 volt ac power outlet. If instrument has been wired for 230 volt operation, connect to 230 volts ac.

b. Set POWER switch to BAT CHG-LINE OPR. After 16 hours, batteries will be fully charged and capable of operating the instrument for at least 30 hours. While

the batteries are being charged, the instrument may be operated the same as for line operation.

### CAUTION!

Since overcharging decreases battery life, it is recommended that the batteries be charged for less than 48 hours and never more than 1 week. When used properly, the batteries will give more than 200 charge-discharge cycles of operation.

## 2-10. OPERATION AS A DC DIFFERENTIAL VOLTMETER

- Perform preliminary operation as stated in paragraph 2-3 or 2-5.
- Connect unknown voltage between INPUT and COMMON post.
- Turn RANGE switch to lowest range that will allow an on-scale reading and note approximate value of unknown voltage as indicated on meter scale.
- If meter reads to left, turn ac-dc polarity switch to negative position. The meter needle will deflect to right. This is because polarity of unknown voltage is negative.
- Noting position of decimal point, set five voltage readout dials to approximate voltage determined in step c. For example, if voltage is approximately 35 volts, decimal point will be between B and C voltage readout dials. Therefore, set A dial to 3 and B dial to 5.
- Set NULL switch from TVM to successively more sensitive null ranges and adjust voltage readout dials for zero meter deflection in each null position. When meter needle indicates to the right, magnitude of voltage under measurement is greater than voltage set on voltage readout dials. When indication is to the left, voltage is less than that set on readout dials.
- Read unknown voltage directly from five voltage readout dials.

## 2-11. OPERATION AS AN AC DIFFERENTIAL VOLTMETER

- Perform preliminary operation as stated in paragraph 2-3 or 2-5.
- Set ac-dc polarity switch to AC.
- Connect unknown ac voltage between INPUT and COMMON posts. If one side is grounded, always connect it to the COMMON post.
- Turn RANGE switch to lowest range that will allow an on-scale reading and note approximate value of unknown voltage as indicated on meter scale.
- Noting the position of the decimal point, set five voltage readout dials to approximate voltage determined in step d. For example, if the voltage is approximately 35 volts, the decimal point will be between the B and C voltage readout dials. Therefore, set A dial to 3 and B dial to 5.
- Set NULL switch to successively more sensitive null ranges and adjust voltage readout dials for zero meter deflection in each null position. When meter needle indicates to the right, magnitude of voltage under measurement is greater than voltage set on voltage readout dials. When indication is to the left, voltage is less than that set on readout dials.

- Read unknown voltage directly from the five voltage readout dials.

## 2-12. OPERATION AS A CONVENTIONAL VOLTMETER

2-13. If it is desired to use the instrument as a conventional 3% voltmeter only, additional ranges can be made available by converting the NULL ranges to conventional voltmeter ranges. This is made possible by setting the voltage readout dials to zero. Proceed as follows:

- Perform preliminary operation as stated in paragraph 2-3 or 2-5.
- Consult figure 2-3, and select full scale voltage deflection desired. If approximate value of voltage to be measured is unknown, select the 1000 volt range initially.
- Set ac-dc POLARITY switch, RANGE switch, NULL switch, and voltage dials as indicated for the range selected.
- Connect voltage to be measured between INPUT and COMMON posts. If one side is grounded, always connect it to the COMMON post.
- Read voltage from meter scale. Deflection to right indicates an unknown dc voltage is of positive polarity. An unknown ac voltage will always deflect to the right.

FULL-SCALE DEFLECTION	AC-DC POLARITY SWITCH	RANGE SWITCH	NULL SWITCH	VOLTAGE DIALS
DC:				
1000-0-1000	+	1000	TVM	No effect
100-0-100	+	100	TVM	No effect
10-0-10	+	10	TVM	No effect
1-0-1	+	1	TVM	No effect
0.1-0-0.1	+	1	0.1	All zero
0.01-0-0.01	+	1	0.01	All zero
0.001-0-0.001	+	1	0.001	All zero
0.0001-0-0.0001	+	1	0.0001	All zero
AC:				
0-1000	AC	1000	TVM	No effect
0-100	AC	100	TVM	No effect
0-10	AC	10	TVM	No effect
0-1	AC	1	TVM	No effect
0-0.1	AC	1	0.1	All zero
0-0.01	AC	1	0.01	All zero
0-0.001	AC	1	0.001	All zero

Figure 2-3. TVM RANGES

## 2-14. MEASUREMENT OF VOLTAGE EXCURSIONS ABOUT A NOMINAL VALUE

- Perform preliminary operation as stated in paragraph 2-3 or 2-5.
- Set ac-dc polarity switch to desired position.
- Connect voltage to be observed between INPUT and COMMON posts. If one side is grounded, always connect it to the COMMON post. Deflection to the left indicates the voltage being measured is negative dc; set polarity switch to the negative position in this case. This will cause meter pointer to deflect to the right.
- Set RANGE switch to lowest range which will give an on-scale meter indication and note nominal value of voltage indicated.
- Set five voltage readout dials to nominal voltage.

f. Turn NULL switch to lowest position that will allow voltage excursions to remain on scale.

g. Read voltage excursions from meter. Note that full scale right and left meter deflections are equal to the NULL range setting (disregarding 10% over-range at end of scale). Meter deflection to the right indicates that magnitude of voltage under observation has increased above the nominal value while deflection to the left indicates it has decreased.

## 2-15. RECORDING VOLTAGE EXCURSIONS

2-16. Recorder output binding posts and an output level control are provided on the 887A and 887AB for monitoring the excursions of an unknown voltage from the voltage indicated by the voltage readout dial settings. If the leakage resistance between the recorder and ground is less than 10,000 megohms, the accuracy of the voltmeter will be impaired. Therefore, the FLUKE Model A88 Isolation Amplifier is recommended for this application. The A88 will allow the use of a wide range of strip chart recorders for recording the voltmeter reading without regard to the input isolation characteristics of the recorder.

### 2-17. USE OF 887A WITH AN A88 ISOLATION AMPLIFIER AND A RECORDER

2-18. To use the A88 Isolation Amplifier and a recorder with the 887A or 887AB, proceed as follows:

- a. Set A88 POWER switch to ON.
- b. When batteries are being used as a power source for A88, measure voltage at BATT TEST jacks. If voltage is between 11.7 and 14 volts DC, the batteries are satisfactory for use. However, if battery voltage is below 12.8 volts, batteries are approaching end of their useful life and should be replaced.
- c. Connect RECORDER OUTPUT terminals of differential voltmeter to INPUT terminals of isolation amplifier with teflon leads.
- d. Connect OUTPUT terminals of isolation amplifier to recorder input terminals.
- e. Perform preliminary operation as stated in paragraph 2-3 or 2-5.
- f. Short INPUT post to COMMON post and set switches on voltmeter as follows:

RANGE	10
NULL	1
voltage readout dials	1.00000

The meter will indicate full scale (-1.0). This provides up to a maximum of at least 20 millivolts at RECORDER OUTPUT terminals depending on setting of AMP ADJ control.

g. Turn on recorder and set recorder gain so that a recorder input of either  $\pm 2$  volts or near maximum if maximum is below  $\pm 2$  volts, will cause recorder deflection desired for full scale deflection of differential voltmeter.

h. Adjust AMP ADJ control on rear of differential voltmeter until recorder deflection obtained is that desired to correspond to full scale deflection of the differential voltmeter.

i. Remove short from INPUT to COMMON post. The voltmeter and recorder are now ready for recording the measurement of voltage excursions about a nominal value. Proceed as instructed under paragraph 2-14.

## 2-19. USE OF 887A WITH A RECORDER

2-20. To use a recorder with the 887A or 887AB proceed as follows:

- a. Connect RECORDER OUTPUT terminals of differential voltmeter to input terminals of recorder with teflon leads.

*Note!*

Do not ground either of the voltmeter RECORDER OUTPUT terminals or either of the recorder input terminals. If any of these terminals are grounded, current will be drawn from the Kelvin-Varley divider and the voltmeter will no longer be accurate.

- b. Perform preliminary operation as stated in paragraph 2-3 or 2-5.

- c. Check for excessive electrical leakage as follows:

- (1) Connect a voltage to the input of the 887A and differentially measure its potential in the most sensitive null range.

- (2) Alternately connect and disconnect the recorder leads from the output terminals of the 887A while noting the meter needle deflection. More than one major scale division deflection (10% of null range) indicates that excessive leakage has been introduced by the recorder. This will impair the accuracy of the 887A voltmeter.

- (3) Disconnect the voltage.

- d. Short INPUT post to COMMON post and set switches on voltmeter as follows:

RANGE	10
NULL	1
voltage readout dials	1.00000

The meter will indicate full scale (-1.0). This provides up to a maximum of at least 20 millivolts at RECORDER OUTPUT terminals depending on setting of AMP ADJ control.

- e. Adjust AMP ADJ control until recorder deflection obtained is that desired to correspond to full scale deflection of the voltmeter.

- f. Remove short from INPUT to COMMON post. The voltmeter and recorder are now ready for recording the measurement of voltage excursions about a nominal value. Proceed as instructed under paragraph 2-14.

## 2-21. MEASUREMENT OF HIGH RESISTANCE

2-22. One of the features of the 887A voltmeter is its ability to be used as a megohmmeter for rapid measurements of high resistance from 10 megohms to 11,000 megohms with a typical accuracy of 5%. The following

equation may be used to compute the resistance in megohms of an unknown connected to the input binding posts when the RANGE switch is set to 10:

$$R_X = R_i \left( \frac{E}{E_m} - 1 \right) \text{ megohms}$$

where:

$R_X$  is the unknown resistance in megohms.

$E$  is the voltage indicated by the voltage readout dials.

$E_m$  is the voltage indicated on the meter.

$R_i$  is the input resistance of the TVM circuit in megohms. 10 for the 1 and 0.1 null range and 1 for the 0.01 and 0.001 null range on the 10 volt range.

2-23. For rapid measurement of resistance between 10 megohms and 11,000 megohms, proceed as follows:

- Perform preliminary operation, paragraph 2-3 or 2-5.
- Set RANGE switch to 10 and NULL switch to 1.
- Connect unknown resistance between INPUT post and COMMON post. Use short isolated leads to prevent measurement of leakage resistance between leads.
- Adjust voltage readout dials for full scale meter deflection (-1.0). If full scale deflection cannot be obtained with NULL switch set to 1, set NULL switch to 0.1 or 0.001.
- Determine value of unknown resistance from figure 2-4.

## 2-24. NOTES ON MEASURING AC OR DC VOLTAGES

### 2-25. GROUND LOOP PRECAUTIONS

2-26. Ground loop currents should be avoided to assure accuracy when making measurements. Potential differences are often found at different points on power system grounds. When this is the case, current may flow from the power system ground through the 887A and the equipment under measurement and back to the power system ground. To avoid this when system being measured is grounded, do not connect 887A COMMON binding post to chassis ground post.

### 2-27. USE OF SHORTING LINK

2-28. A 0.01 uf capacitor (C1) is connected from the COMMON binding post to the chassis ground post to reduce the effect of circulating ac currents from the transformer. In some cases, it is possible for C1 to acquire a charge. For example, C1 will become charged when making common mode voltage measurements. This condition may cause an error on low level measurements (under 5 volts) due to C1 discharging through the Kelvin-Varley divider and leakage resistance to ground. Connecting the shorting link from the COMMON post to the ground post for a few seconds will discharge C1 and thus prevent an inaccurate indication.

### 2-29. BATTERY CHECKING

2-30. If the voltmeter is left in the battery operating mode for an extended period of time, the batteries will

Range of Unknown Resistance	Null Switch Position	To Obtain Value Of Unknown In Megohms When Meter Indicates Full Scale
10 MΩ to 100 MΩ	1	Multiply amount set on voltage readout dials by 10 and subtract 10.
90 MΩ to 1090 MΩ	0.1	Multiply amount set on voltage readout dials by 100 and subtract 10.
1,000 MΩ to 11,000 MΩ	0.001	Multiply amount set on voltage readout dials by 1000.

Figure 2-4. RESISTANCE MEASUREMENTS

become discharged. When the batteries are left in a completely discharged state with the voltmeter turned off, their voltage will recover with time. It is possible that the batteries may have recovered enough for the meter to indicate they are charged when the power switch is first set to battery check. However, after a few seconds, the battery voltage will fall and the meter will indicate that the batteries need to be charged. It should also be noted that the voltage characteristic of the nickel-cadmium batteries is very flat except near full charge and complete discharge. Therefore, when the batteries are checked, the meter needle deflection will not be proportional to the remaining ampere-hour capacity of the batteries. Just after the batteries are charged, the meter needle will indicate near full scale. However, most of the time the batteries are charged, the meter needle will indicate near half scale. A few hours before the batteries need a recharge, the meter needle will indicate just within the battery ok region.

### 2-31. EFFECT OF COMMON MODE VOLTAGES

2-32. Common mode errors are caused by leakage currents passing through ground loops. Since great care has been taken in the design and construction to insulate the circuitry from chassis ground, accurate dc common mode measurements up to 1000 volts dc above ground can be made with the 887A and 887AB. The dc common mode rejection is at least 134 db (5,000,000 to 1) or 0.2 uv error per common-mode-volt all the way up to 70% relative humidity. However, since the leakage resistance is dependent on dampness, the dc common mode error is typically much less at lower relative humidities. Thus, common mode measurements should be made with a relative humidity below 70%. Also, if the common mode voltage is greater than 50 volts, the measurement should be made several minutes after hookup for best accuracy. This is due to the time it takes to charge stray capacities to ground through the extremely high leakage resistances.

## 2-33. NOTES ON MEASURING DC VOLTAGES

### 2-34. EFFECT OF AC COMPONENTS ON DC MEASUREMENTS

2-35. An ac component of several times the unknown dc may be present on the unknown and the 887A will always indicate well within the specifications for frequencies



over a few hundred cycles. An ac component may have an adverse effect if it is of a low frequency or if it has a frequency that is a multiple or submultiple of the chopper frequency. A triple section low pass filter (R201, C201, R202, C202, R203, and C203) is used at the input of the null detector to reduce any ac present on the dc being measured. At lower frequencies, this low pass filter is less effective and the magnitude of the ac component is more significant. If this frequency is below 100 Hertz, the accuracy may no longer be with specifications. For example, a 60 Hertz ac voltage that is 1% of the input will cause an error of approximately 0.001% which is well within the specifications. This 1000:1 rejection of ac also applies until the ac voltage is 1000 times the null range. For example, on the .01 volt null range, the ac rejection of 1000:1 applies up to 10 vac. When the frequency is very close to a multiple or submultiple of the chopper frequency (approximately 84 Hertz), the meter needle will oscillate at the difference frequency. If ac components that affect the accuracy are ever encountered, additional filtering will be required. For an ac of a single frequency, a twin-T filter is effective and has the advantage of low total series resistance. For an ac variable frequency, an ordinary low pass filter may be used. In either case, high quality capacitors of high leakage resistance should be used.

#### 2-36. MEASUREMENT OF NEGATIVE VOLTAGES

2-37. Because of a polarity switch, voltage which are negative with respect to ground as well as the more commonly encountered positive voltages may be measured with equal facility. If the INPUT post is connected to the metal case, either at the 887A or at the source under measurement, the accuracy of the voltmeter may be reduced. However, with the polarity switch, the INPUT post never has to be connected to ground. If the unknown voltage is grounded, always connect the grounded side to the COMMON post and use the polarity switch to obtain the proper result.

#### 2-38. NOTES ON MEASURING AC VOLTAGES

##### 2-39. ERRORS DUE TO DISTORTION

2-40. The ac to dc converter in the 887A is an average measuring device calibrated in rms. The converter will put out a dc voltage that is proportional to 1.11 times the average value of the ac input voltage. Thus, if the input signal is not a true sinusoid, the 887A reading is probably in error because the ratio of rms to average is usually not the same in a complex wave as in a sine wave. The magnitude of the error is dependent on magnitude of the distortion and on its phase and harmonic relationship with respect to the fundamental. Figure 2-5 indicates how the accuracy will be affected by various harmonics for different percentages of distortion. If the distortion present in the signal is composed of even harmonics and is less than 2%, the error between the 887A reading and true rms is minor. A larger error can occur if the distortion is composed of odd harmonics, especially the third harmonic. Note that for 2% of third harmonic distortion the error in the reading could range from 0 to 0.687%.

Harmonic	% Distortion	% Error From True RMS*	
		Maximum Positive	Maximum Negative
Any even harmonic	0.1	0.000	0.000
	0.5	0.000	0.0001
	1.0	0.000	0.005
	2.0	0.000	0.020
Third harmonic	0.1	0.033	0.033
	0.5	0.167	0.168
	1.0	0.328	0.338
	2.0	0.667	0.687
Fifth harmonic	0.1	0.020	0.020
	0.5	0.099	0.101
	1.0	0.195	0.205
	2.0	0.380	0.420

\*Error depends upon phase relationship between harmonic and fundamental, i. e. error can be any value between maximum positive and maximum negative, including zero.

Figure 2-5. PERCENT ERROR DUE TO HARMONIC DISTORTION

##### 2-41. ERRORS DUE TO GROUNDING

2-42. In the 887A there is a 0.01 uf capacitor connected from the COMMON terminal (middle post) to chassis ground. If it is desired to make measurements where the voltage to be connected to the lower input terminal is not at ground potential, a line cord adapter must be used to isolate the 887A chassis from line ground. Otherwise, the 0.01 uf capacitor would place an ac load on the circuit being measured.

##### 2-43. INTERNAL CONVERTER NOISE

2-44. When the instrument is shorted in the ac mode, the converter may produce a residual noise output of approximately 100 uv. This noise voltage will cause an insignificant error as long as ac input signals of 1 mv or larger are applied to the instrument. Figure 2-6 shows a typical half wave of the signal voltage at the output of the converter amplifier. It is easily seen that the noise contributes very little to the average value of the signal and is well within the 2.6% accuracy of the instrument at 1 mv. Also for input signals over 1 mv, the instrument is noise free to within 2 parts per million of the input range. For example, on the 1 volt input range the instrument will contribute less than 2 uv of noise to any measurement.

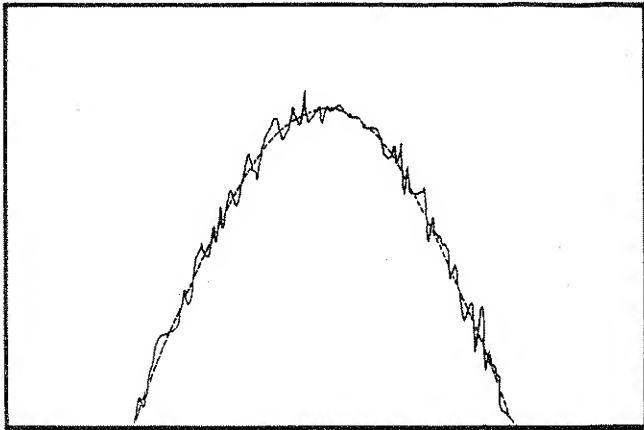


Figure 2-6. SIGNAL VOLTAGE WITH  
CONVERTER NOISE

#### 2-45. MOST SENSITIVE NULL RANGE ON AC

2-46. The most sensitive null range for each input range should be used with caution when measuring ac voltages. Most ac sources are not stable enough to be used on this range. For example, if 1.0 volt is measured with the range switch set to 1 and the null switch set to 0.0001, the null detector sensitivity is 100 microvolts full scale. Since 100 uv is 0.01% of 1.0 volt, an ac source with a stability worse than  $\pm 0.01\%$  will cause the 887A meter pointer to swing from one end of the meter scale to the other. Also, if the input is shorted with the range switch set to 1 and the null switch set to 0.0001, the meter needle may deflect more than full scale due to converter noise. However, as pointed out in paragraph 2-43, converter noise will not impair the accuracy for input signals greater than 1 mv. Thus, any excessive erratic meter needle movement is due to ac source stability.



## SECTION III

# THEORY OF OPERATION

### 3-1. INTRODUCTION

3-2. Figure 3-1 shows the block diagram for the 887A Differential Voltmeter. As seen in this figure, the circuit is mainly composed of an ac to dc converter, a dc input attenuator, a dc transistorized voltmeter (tvm), and an extremely accurate 0 to 11 volt reference. The dc input attenuator reduces the input voltage by a factor of 100 on the 1000 and 100 volt dc range. The

tvm uses a null detector, an attenuator, and a meter to obtain high sensitivity. The 0 to 11 volt reference uses a range divider and a Kelvin-Varley attenuator to make the output of two well regulated zener diodes adjustable. Refer to the functional schematic following Section VI for more detail. This schematic is designed to aid in the understanding of circuit theory and troubleshooting. The signal flow is from left to right and the components are laid out in a functionally logical manner.

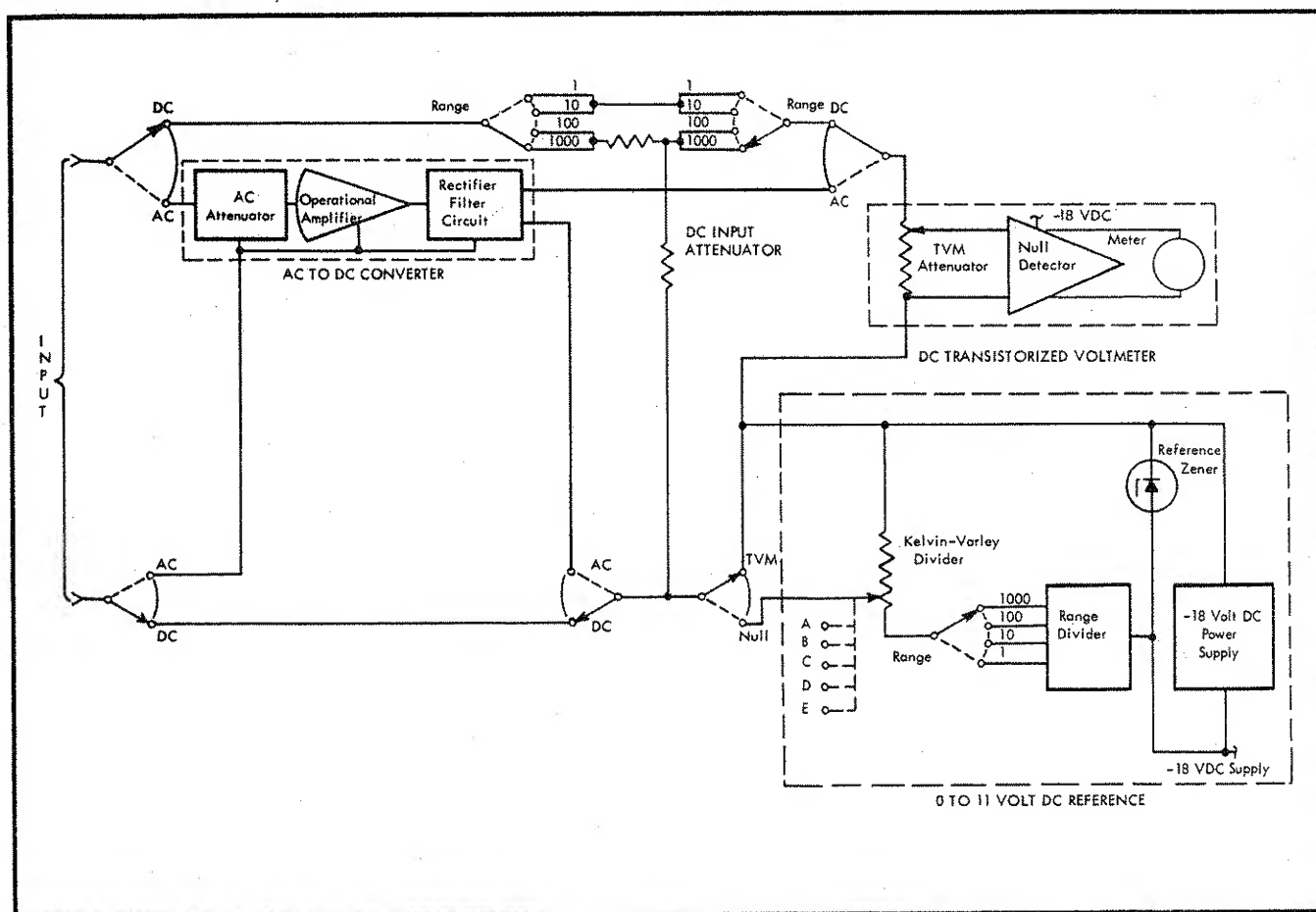


Figure 3-1. 887A DIFFERENTIAL VOLTMETER BLOCK DIAGRAM

3-3. The overall operation of the voltmeter may be summarized as follows. To measure the approximate value of a dc voltage between 0 and 11 volts, the unknown voltage is connected directly across the tvn attenuator. This attenuator is set in such a way that the maximum voltage for each range is reduced to a signal of 1 millivolt (100 microvolts for the 1 volt range in the highest null mode). The signal is then applied to the null detector and causes 100 microamperes to flow through the meter for full scale deflection. To accurately measure this dc voltage, the unknown voltage is connected across the series combination of the tvn and the 0 to 11 volt reference. The reference voltage is then adjusted with the five voltage readout dials until it matches the unknown voltage as indicated by the tvn. For voltages between 11 and 1100 volts, the dc input attenuator divides the unknown voltage by 100. The 883A then operates essentially the same as for measurements from 0 to 11 volts. All ac measurements are made by first converting the ac input voltage to a dc voltage by means of the ac to dc converter. The 887A then operates essentially the same as for approximate and accurate dc measurements.

3-4. In order to provide for a more complete understanding of the 887A voltmeter, the following paragraphs describe each section of the circuit in detail.

### 3-5. DC INPUT ATTENUATOR

3-6. Since the instrument contains a 0 to 11 volt reference, the unknown voltage is measured by comparing it to a known voltage with the aid of a null detector only on the 1 and 10 volt range. On the 100 and 1000 volt range, the dc input attenuator (R100 through R104) divides the unknown voltage by 100 and this attenuated voltage is then measured by the potentiometric principal. Thus, after attenuation by 100, the 100 and 1000 volt ranges are reduced to the equivalent of 1 and 10 volt ranges. The dc input attenuator is extremely accurate and has excellent long term stability. The 10K variable resistor (R103) is used during factory calibration to setup the proper division ratio. This adjustment can then be performed as required at regular calibration intervals.

### 3-7. DC TRANSISTORIZED VOLTMETER

#### 3-8. GENERAL

3-9. The dc tvn is composed of an attenuator, a null detector, and meter. The heart of the dc tvn is the null detector in which the dc signal is modulated by an electromechanical chopper, amplified by a five stage resistance-capacitance coupled amplifier, rectified by a transistor switch, and finally filtered to produce a dc output. The null detector has a high amount of negative current feedback. This makes the proportion of the output current feedback approximately equal to the signal voltage divided by the resistance of the feedback resistor, regardless of the amplifier characteristics. The high negative feedback also makes the amplifier relatively insensitive to the gain changes in individual transistors due to aging, and replacement. The output current from the null detector is indicated on a meter that has tautband suspension. This suspension does away with all friction associated with meter pivot sticki-

ness. Thus, any tendency for the meter pointer to stick at one point of the scale and then jump to another point is eliminated. The tvn attenuator is used to reduce the voltage span of each range to a common range usable by the null detector to produce proper meter deflection.

#### 3-10. NULL DETECTOR

3-11. The null detector is a current feedback amplifier that drives a meter. Any feedback amplifier is essentially a null seeking device. That is, it tends to make the voltage fed back to the input equal to the input voltage. In a current feedback amplifier, the feedback voltage is equal to the voltage drop across a fixed resistor caused by the output current or a portion of the output current. At the input to the 887A null detector R201, C201, R202, C202, R203, and C203 form a triple section low pass filter that reduces any ac component present on the dc voltage being measured. The difference between the voltage appearing at the output of the filter and the voltage developed across feedback resistor R236 is converted to an alternating voltage by G201, an 84 hertz chopper. The voltage across R236 is proportional to the current flowing in the meter. The alternating voltage created by G201 is amplified by a five-stage solid-state amplifier. The first stage is a p-channel field effect transistor (Q201). The field effect transistor provides both high impedance and low noise input characteristics. The next four stages consist of two transistor doubletons (Q202 to Q205). During one portion of the chopper cycle, the output of the amplifier is clamped to approximately null detector common potential by Q206, a transistor switch. The transistor switch is gated in synchronization with the chopper since the gating pulse comes from the voltage that is used to drive the chopper. During the other portion of the chopper cycle, the output of the amplifier is filtered by R-C filter R225-C219 to provide a dc current for the meter. A portion of the current that flows through the meter is shunted back to the 200Ω feedback resistor R236 thus completing the feedback loop. The null detector has a basic sensitivity of 1 millivolt except in the most sensitive null mode for the 1 and 100 volt range where the sensitivity is 100 microvolts. For the two most sensitive null modes in the 100 and 1000 volt range, the sensitivity is boosted 10% to compensate for the loading effect of the tvn attenuator on the dc input attenuator. The output resistance of the dc input attenuator is 100K and the input resistance of the tvn dc attenuator is 1 meg. Thus, when monitoring voltage excursions, much more accurate off null readings are obtained due to the 10% boost in null sensitivity.

#### 3-12. TVM ATTENUATOR

3-13. In the dc tvn mode, two positions on the tvn attenuator selected by range switch section S2H provide the necessary reduction of the 1 and 10 volt ranges for proper null detector input. The same two positions on the tvn attenuator are used for the 100 and 1000 volt ranges because the input attenuator divides the input signal by 100 and thus reduces the 100 and 1000 volt ranges to the equivalent of 1 and 10 volt ranges. In the differential mode, the voltage difference (unknown voltage, or unknown voltage divided by 100, minus reference voltage) is reduced as necessary by positions on the tvn

attenuator selected by null switch sections S3H, S3G, and S3E to provide the basic null detector inputs of 1 millivolt or 100 microvolts.

3-14. In the ac tvn mode, null switch section S3H and ac-dc polarity switch section S4E provide connection to only one position on the tvn attenuator regardless of where the range switch is set. Also, in the ac differential mode, the voltage difference (converter output voltage minus reference voltage) is reduced by the same positions on the tvn attenuator as for 1 volt dc differential measurements. This is because the output of the ac-dc converter is 1 volt dc for full input on each range.

### 3-15. INPUT RESISTANCE

3-16. For the tvn, low sensitivity, and medium low sensitivity modes, the input resistance of the tvn attenuator is 10 megohms (R4 through R7). For the medium high and high sensitivity modes, the input resistance of the tvn attenuator is 1 megohm (R4 through R7). However, this is not the input resistance of the 887A for the dc tvn and dc differential mode. For the 1 and 10 volt range, the input resistance is determined by dividing the unknown voltage by the current drawn from the unknown. The current drawn from the unknown is equal to the difference between the unknown terminal voltage and the internally known voltage divided by the resistance of the tvn attenuator. The equation for input resistance can therefore be written as:

$$R_{in} = \frac{E_u}{I_u} = \frac{E_u R_a}{|E_u - E|} = \frac{E_s (R_a + R_s)}{|E_s - E|} - R_s$$

where:

$R_{in}$  = input resistance of voltmeter

$E_u$  =  $E_s - I_u R_s$  = terminal voltage of unknown

$I_u$  = current drawn from unknown

$E_s$  = source voltage of unknown

$R_s$  = source resistance of unknown

$R_a$  = input resistance of tvn attenuator

$E$  = voltage indicated by voltage readout dials

$| |$  = absolute value (magnitude only)

Thus, the input resistance is essentially infinite (leakage resistance across input is in the order of  $10^{12}$  ohms) at null when  $E$  is equal to  $E_u$  and  $E_s$ . For the 100 and 1000 volt range, the dc input attenuator is always connected across the input terminals. Thus, the input resistance is equal to the resistance of the dc input attenuator which is 10 megohms.

3-17. The input impedance for the ac tvn and ac differential mode depends on the input impedance of the ac to dc converter and its attenuator. The ac input impedance is thus 1 megohm and 40 picofarads.

### 3-18. CHOPPER DRIVE CIRCUIT

3-19. The chopper drive circuit determines the chopper timing frequency of 84 Hz. The circuit is symmetrical with the transistors biased so that they can conduct simultaneously. However, cross-coupling capacitors C105 and C106 force Q106, Q109 and Q107, Q108 to conduct alternately. This results in a square wave varying from about 0 to 6 volts that drives chopper coil G201. The symmetry and frequency of the waveform are adjusted with R126 and R124 respectively.

### 3-20. NULL DETECTOR POWER SUPPLY

3-21. The voltage for null detector amplifier stages Q201 through Q205 is supplied by the same -18 volt power supply that is used to power the 0 to 11 volt reference. The voltage for chopper drive circuit transistors Q106 through Q109 is obtained from a half-wave rectifier consisting of diode CR101 and an R-C filter network (R105 and C101) that supplies 6 volts dc. Current determining resistors R238 and R240, diodes CR201 and CR202, and divider resistor R239 provide a compensating voltage for the purpose of adjusting the null detector to zero with R239 when there is no signal input. Diode CR201 keeps one side of R239 at approximately +0.6 volt dc with respect to the null detector common while diode CR202 keeps the other side at approximately -0.6 volt dc.

### 3-22. EFFECT OF AC COMPONENTS ON DC MEASUREMENTS

3-23. The only ac voltage component that will reduce the accuracy of the 887A is one that either saturates the null detector or one that beats with the chopper frequency. Since the voltage required for saturation is greater than that required for beating, the null detector is most sensitive to an ac component with a frequency that is a submultiple or a low multiple of the chopper frequency. However, this is easy to detect because the meter will beat at the difference frequency. The low pass filter at the input of the chopper-amplifier will attenuate any ac component. The magnitude of the ac voltage appearing at the output of the filter depends on both its amplitude and frequency before filtering. For all practical purposes, one should never encounter any trouble above a hundred cycles. Below this, the filter may not attenuate the ac component enough. However, this is not as bad as it appears. A 60 cycle ac voltage that is 1% of the input voltage will cause an error of approximately 0.001% which is well within specifications. If ac components that affect accuracy are ever encountered, additional filtering as set forth in the operating instructions will eliminate the problem.

### 3-24. TVM GAIN AND ZERO ADJUSTMENTS

3-25. Variable resistor R239 in the feedback network provides a means of adjusting the output current of the null detector to zero when there is no input signal. The gain of the null detector is adjusted by means of R230 in the feedback network for the 1 millivolt sensitivity and by means of R231 for the 100 microvolt sensitivity.

### 3-26. RECORDER OUTPUT

3-27. The recorder output is picked off divider string R226, R8, and R227. Recorder output AMP ADJ control R8 provides a means of adjusting the output voltage up to a maximum of at least 20 millivolts at full scale deflection (disregarding 10% over-range at end of scale). The voltage at the RECORDER OUTPUT terminals is proportional to the meter reading.

### 3-28. 0 TO 11 VOLT REFERENCE

#### 3-29. GENERAL

3-30. When the 887A is used to make differential dc voltage measurements between 0 and 11 volts, an internal voltage is nulled or matched against the unknown voltage. An extremely accurate reference is therefore required. This is obtained from the 0 to 11 volt reference. The 0 to 11 volt reference is composed of a well regulated -18 volt power supply, a range divider, and a five decade Kelvin-Varley divider. The range divider reduces the voltage from a pair of stable Zener diodes in the -18 volt reference supply to 11 volts for the 10 and 1000 volt dc ranges and to 1.1 volts for the 1 and 100 volt dc ranges before it is applied to the Kelvin-Varley divider. The Kelvin-Varley divider divides its input voltage (11 or 1.1 volts) into over 1, 100, 000 equal increments any number of which may be selected by setting the five decades with the five voltage readout dials. The output of the Kelvin-Varley divider, therefore, provides an extremely accurate reference voltage.

#### 3-31. REFERENCE POWER SUPPLY

3-32. -18 VOLT POWER SUPPLY. The -18 volt power supply uses diode CR102 and filter capacitor C101 to supply unregulated dc voltage to series pass transistor Q101. In the Model 887AB, unregulated dc voltage can also be supplied by a set of batteries (BT1) in the BAT OPR and BAT CHECK modes. The -18 volts is regulated by comparing a sample of the output voltage, tapped off divider string R109, R110 and R111, with the voltage from zener reference diodes CR103 and CR104 in a two-stage differential amplifier. Transistor Q103 is a dual transistor, having matched current gain and matched  $\Delta V_{be}$ , which insures minimum voltage change due to temperature in the -18 volt reference voltage. The output from Q103, which is proportional to the difference between the two inputs, is applied to a second state of differential amplification, Q104 and Q105. The output from Q104 is applied to the base of series pass transistor Q101. The differential amplifier adjusts the voltage drop across the series pass transistor so as to maintain a constant output voltage. The -18 volt provides operating current for the chopper drive multivibrator, and supplies a constant current through R116 and R117 to its own zener reference diodes CR103 and CR104. If the instrument is turned on with the battery voltage below about 5 volts, there is a possibility that transistor Q101 may not begin conduction. Thus, when the power switch is set to BAT CHECK, the meter would indicate an adequate battery change, because all of the voltage drop appears across Q101. When the instrument is first turned on, the base-emitter junction of Q102 is forward biased, and Q102 conducts, which causes transistor Q101 to conduct and become

saturated. As the output voltage of the -18 volt supply rises above -11 volts, transistor Q102 becomes biased off, and the differential amplifier controls the conductance of Q101.

3-33. For instrument serial numbers 618-659, 691 and on, zener diodes CR104 and CR105 are enclosed in a proportionally-controlled oven, Q111, Q112, Q113, and associated components. The oven heater is R147. Transistors Q112 and Q113 are connected as a differential amplifier, with the base voltage of Q113 fixed by R153 and R154. The base voltage of Q112 is set by R150 and R155. Since R155 is temperature-sensitive, the base voltage of Q112 varies inversely with temperature. The output from the collector of Q112, which is proportional to the difference between the base voltages of Q112 and Q113, is applied to the base of Q111 and controls the conduction of Q111, which controls heater current. For example, as the oven temperature increases, the resistance of R155 decreases. This causes a more positive output from the collector of Q112, which reduces the conduction of Q111, thus reducing current through the heater R147, and decreasing heating of R147. C108 eliminates oscillations in control circuit.

#### 3-34. RANGE DIVIDER

3-35. In the 1000 and 10 volt dc range, the Zener reference diode voltage is connected directly to the Kelvin-Varley divider through resistors R119 and R120 by means of range switch sections S2J and S2I. The voltage drop across R119 and R120 reduces the Zener reference voltage to 11 volts at the input of the Kelvin-Varley divider. In the 100 and 1 volt dc range, range resistors (R121, R122, and R123) selected by range switch sections S2J and S2I reduce the voltage to 1.1 volts at the input to the Kelvin-Varley divider. With the ac-dc connection to the range resistors that divide the reference voltage to 1.1 volts. This 1.1 volts is then passed to the Kelvin-Varley divider by ac-dc switch section S4G. The voltage applied to the Kelvin-Varley divider is always 1.1 volts for ac because the maximum output of the ac to dc converter is always 1.1 volts.

#### 3-36. KELVIN-VARLEY DIVIDER

3-37. The five Kelvin-Varley decades composed of resistors R301 to R366, and associated voltage dials A through E provide a means of making the two precision voltages (11 and 1.1 volts) adjustable. The first decade has twelve 5K resistors (a 4,999.2 ohm resistor and a 2 ohm trimmer). Two of these resistors are shunted by the 10K total resistance of the second decade. Between the two wipers of S5 (voltage dial A) then, there is a total resistance of 5K (10K paralleled by 10K). Thus, the first decade divides the voltage across it into eleven equal parts with one of the equal parts appearing across the two shunted resistors. Similarly, the second, third, and fourth decades divide the voltage across them into ten equal parts. Note that the second, third, and fourth decades each have eleven 1K resistors. The resistors may have the same value because padding resistors R328 - R329 and R315 - R316 are used across the third and fourth decades respectively to keep the proper resistance matching. The last decade, with its associated shunt resistors to keep the proper matching, is a variable resistor which can be set to pick off increments equal to less than 1/100 times the voltage across

its input. The Kelvin-Varley resistors are matched for both temperature coefficient and tolerance thus providing an overall accuracy of 0.002% absolute from 1/11 of full scale to full scale. With the null switch in any null range, the output of the Kelvin-Varley divider is connected in series with the TVM attenuator thus providing the accurate 0 to 11 volt or 0 to 1.1 volt reference voltage required.

### 3-38. ADJUSTMENTS

3-39. Variable resistor R111 is used during final factory calibration to set the reference supply to -18 volts. This adjustment is not exceedingly critical and should have to be done only when a component of the reference supply has been replaced. The voltage from the Zener reference diodes is reduced to 11 volts at the input to the Kelvin-Varley divider by adjusting variable resistor R120 during calibration. Range-divider variable resistor R122 may then be adjusted for 1.1 volts at the input to the Kelvin-Varley divider. The 2 ohm trimmer resistors (odd resistors from R301 to R325) and variable padding resistors R338, R351, and R364 should require adjustment only after a component of the Kelvin-Varley divider has been replaced.

### 3-40. AC TO DC CONVERTER

#### 3-41. GENERAL

3-42. The ac to dc converter is composed of an attenuator, an operational amplifier, and a rectifier-filter circuit. A pair of diodes in the rectifier-filter circuit are used to convert the unknown ac into pulsating dc. This pulsating dc is then filtered to obtain a dc voltage that is proportional to the average value of the ac input voltage. The output, however, is calibrated to indicate the rms value of a pure sine wave. An operational amplifier with high negative feedback is used to make the rectification characteristics of the diodes linear and stable. The first stage is an n-channel field effect transistor (Q501). The field-effect transistor provides both high impedance and low noise input characteristics. The next four stages consist of two transistor doubletons (Q502, Q503, Q504, and Q506). Transistor Q505 acts as a dynamic load and thus increases the output impedance of the amplifier. The amplifier achieves a midband loop gain of approximately 70 db with a virtually flat frequency response from 20 Hz to 20 kHz. At the output of the amplifier, full wave rectification is used to return negative feedback to the gate of the field-effect transistor. The high negative feedback makes the amplifier practically noise free and relatively insensitive to gain changes in individual stages due to aging and transistor replacement. An attenuator is used to reduce the ac input voltage on the higher ranges to within the operating level of the converter amplifier.

#### 3-43. CONVERTER POWER SUPPLY

3-44. The auxiliary power supply for the converter is composed of Q507, Q508, Q509, and the associated components. Diode CR506 and filter network R542-C523 supply unregulated dc voltage to series pass transistor Q507. In the 887AB, unregulated dc voltage is supplied from a set of batteries, BT2, in the BAT

CHECK and BAT OPR modes. The emitter voltage of Q509 is set by Zener diode CR505. The base input to Q509 is taken from a divider string, R538, R539, and R540, which samples the output voltage of the -18 volt supply. Any variation in the -18 volts varies the base drive of Q509, which varies the output from the collector load of Q509. Since the output of Q509 drives Q508, the collector current of Q508 continuously adjusts the conductance of Q507 to maintain the auxiliary voltage constant at the value determined by the setting of R539.

### 3-45. OPERATION

3-46. All ac measurements are made by first converting the ac input voltage into a dc voltage. The converter provides a dc output of 1 volt when full range voltage is applied to the 887A in each ac range. In the 1 volt ac range, the ac-dc polarity switch and the range switch connect the input binding posts directly to the converter input. The converter gain is of such a value that the dc output voltage is equal to the rms value of the converter input voltage for a sine wave. For the 1000, 100, and 10 volt ac ranges, a separate input attenuator for each range reduces the unknown ac voltage by a factor of 1000, 100, and 10 respectively. The operation of the converter is then the same as for the 1 volt range. Thus, an output of 1 volt dc is provided for full range input of a pure sine wave on any ac range.

### 3-47. ADJUSTMENTS

3-48. The converter gain is adjusted with R503 in the feedback loop of the operational amplifier. Capacitor C502 in the feedback loop is used to adjust the high frequency response of the converter. The attenuation of the 1000, 100, and 10 volt attenuators are adjusted with R410, R406, and R403 respectively. Capacitors C405, C403, and C401 are used to adjust the high frequency response attenuators. The bias of field-effect transistor Q501 should require adjustment with R508 only when Q501 or a component in its drain-source circuit is replaced. The amplifier output level at the collector of Q506 should require adjustment with R522 only if Q505, Q506, or a component in one of these stages is replaced.

### 3-49. AC-DC POLARITY SWITCH

3-50. The ac-dc polarity switch is provided for selecting either the ac or dc mode of operation. When the ac-dc polarity switch is set to AC, the ac to dc converter is switched into the circuit by sections S4A, S4B, S4C, and S4D. Also, sections S4H and S4G are used to switch 1.1 volts dc to the Kelvin-Varley divider. Section S4E is used to provide proper attenuation in the tvn attenuator.

3-51. For the dc mode of operation, the ac-dc polarity switch may be set to the positive or the negative dc position. As seen in figure 3-2, the polarity switch reverses the transistorized voltmeter - reference voltage combination with respect to the input. Note that a 0.01 uf capacitor (C1) is connected from the COMMON post to the chassis ground post to reduce the effect of ac circulating currents. If the instrument did not contain a polarity switch, the grounded side of any unknown

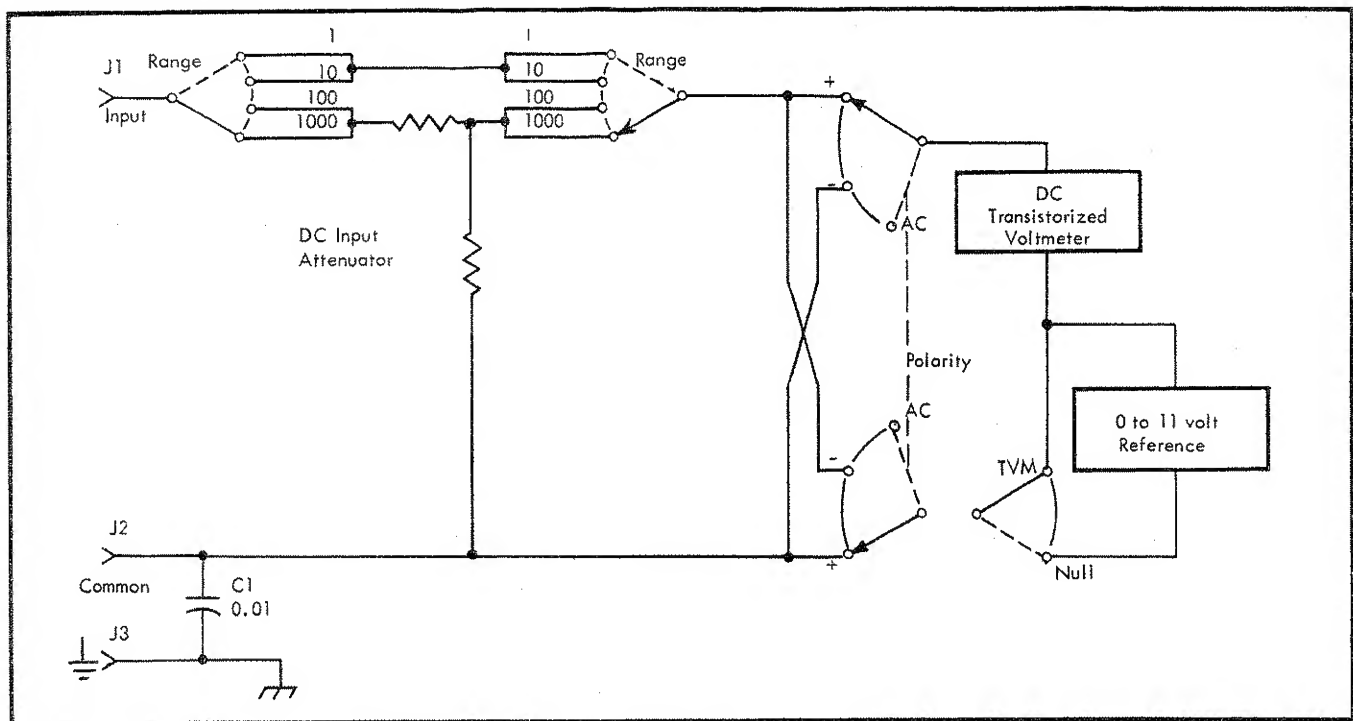


Figure 3-2. FUNCTION OF POLARITY SWITCH

voltage that is negative with respect to ground would have to be connected to the INPUT post. This would ground the INPUT post and effectively place C1 across the input. With this capacitance connected across the

circuit being measured several problems would arise. The polarity switch provides equal convenience in measuring positive and negative voltages without the occurrence of these problems.



